TILT AND AQUIFER HYDRAULIC-HEAD CHANGES NEAR AN EARTH FISSURE IN THE SUBSIDING MIMBRES BASIN, NEW MEXICO

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Earth fissures, related spatially and temporal to basinwide ground-water pumpage and ground-water level declines, occur in at least 13 locations throughout the Mimbres Basin south of Deming, New Mexico. Both the maximum drawdown, in excess of 33 m between 1910 and 1987, and 12 of the fissure locations occur near the center of the 880 km^2 cone of depression in the aquifer potentiometric surface (Contaldo and Mueller, 1991). Subsidence above the center of the cone, estimated from protruding well heads, is believed to be on the order of several decimeters to one meter.

Tilts and ground-water level changes near the Cox earth fissure located in SE/4, SW/4, T25S, R9W were monitored between January and December 1992, using a network of 4 biaxial borehole tiltmeters, 2 piezometers, and a nearby domestic well (fig. 1) instrumented with pressure transducers (Haneberg and Friesen, 1993; Friesen, 1992; see Carpenter abstract for related discussion of deformation measurements near an earth fissure in the Picacho Basin, Arizona). The tiltmeters are sanded into 20-cm-diameter steel casings, so that tilts are averaged over the length of the casing (approximately 2 m for T-A and T-D, and approximately 5 m for T-B and T-C). The objective of this study was to compare observed tilts near the fissure with the deformation patterns predicted by models of simple plane strain draping and differential compaction perpendicular to the trace of the fissure. Previous work at this site included shallow seismic reflection and gravity surveys across the fissure (Haneberg and others, 1991).

The static ground-water levels measured in the piezometers in December 1991 were about 42.6 m below land surface, with a head difference between the piezometers of about 4 cm across the fissure. The depth to water in the piezometers increased approximately 22 cm between December 1991 and late September 1992 (fig. 2)

Resolution of the tiltmeters is 0.1 microradian over a range of $\pm$800 microradian, and resolution of the pressure transducers is 0.013 kPa (the equivalent of about a 1.3 mm height of water) over a range of 0 to 103 kPa (about 0 to 10.6 m height of water). Data were recorded hourly using a digital data logger. Short-term tilt and water-level records exhibit diurnal and semi-diurnal cycles superimposed on long-term trends, with daily tilt amplitudes on the order of $\pm$0.1 microradian and daily water level amplitudes on the order of 1.0 cm. Virtually all of the observed variability can be accounted for by a least-squares regression model incorporating 8 earth tide, barometric, and annual irrigation harmonics, plus a monotonic linear trend (Friesen, 1992; Haneberg and Friesen, 1993; see Galloway abstract for additional information on the analysis of earth tides and atmospheric loading signals in time-series of ground-water level changes). Because a barometer was not available at the field site, however, it is impossible to separate the tidal and barometric components in our data. Recasting tilt values as differential horizontal displacements between the top and bottom of the tiltmeter and assuming zero vertical displacement, we estimate dilation

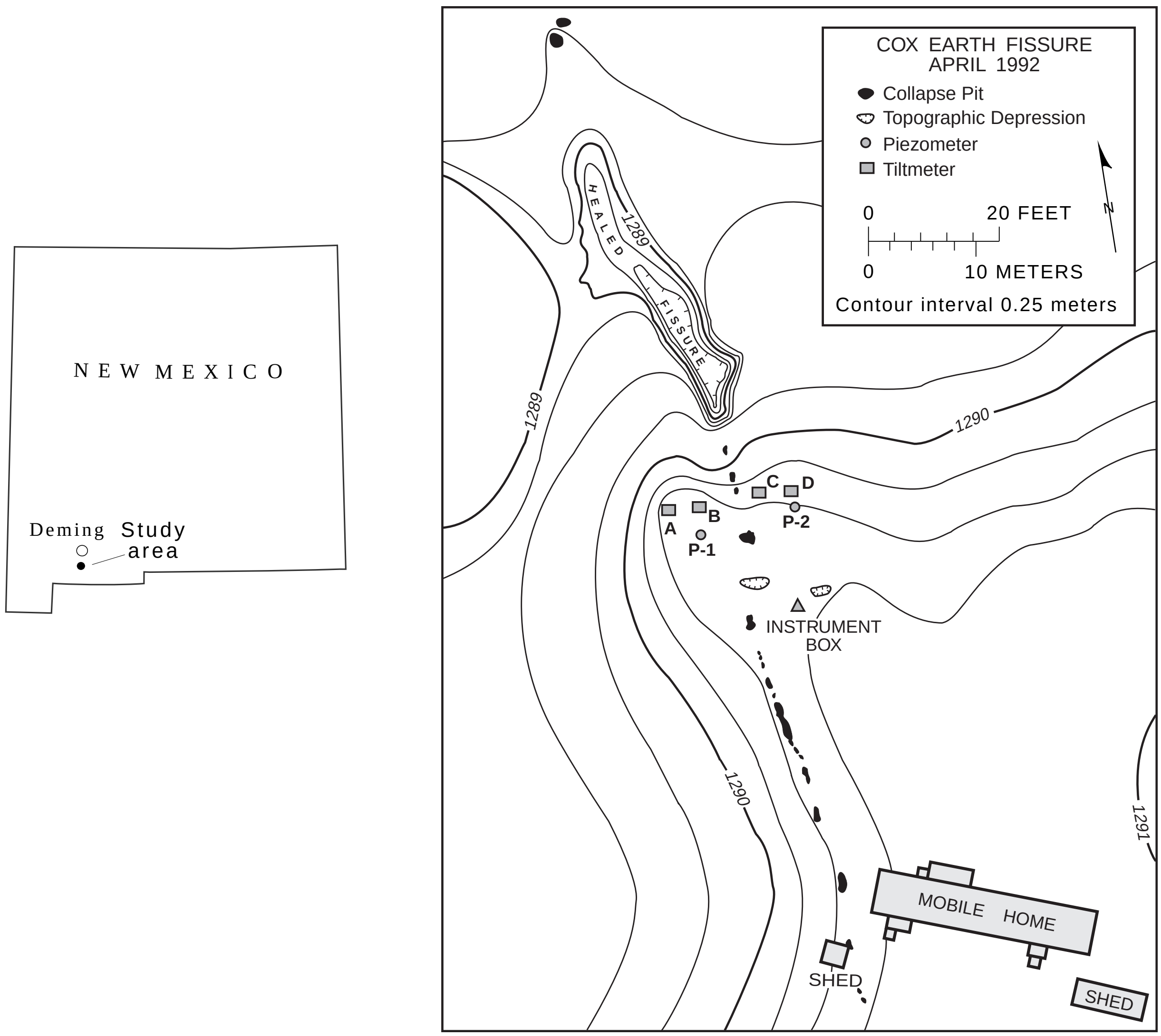

Figure 1. Plane table topographic map of the field site near the Cox earth fissure, showing the trace of the fissure; tiltmeters A, B, C, and D; and piezometers P-1 and P-2. The topographic ridge running through the site is believed to be the surficial expression of a buried channel deposit interpreted on shallow seismic reflection profiles (Haneberg and others, 1991). Tiltmeters T-A and T-D are approximately 2 m deep, and tiltmeters T-B and T-C are approximately 5 m deep.

associated with the diurnal fluctuations to be on the order of 0.01 microstrain, which is the same order of magnitude commonly associated with earth-tide deformation (Bredehoeft, 1967). Daily water level maxima generally correspond to daily tilt maxima, and suggest that the fissure closes as water level rises (see Carpenter abstract for related finding). Because of complicated wave forms, however, we can only speculate that the fissure must open slightly as the water level drops.

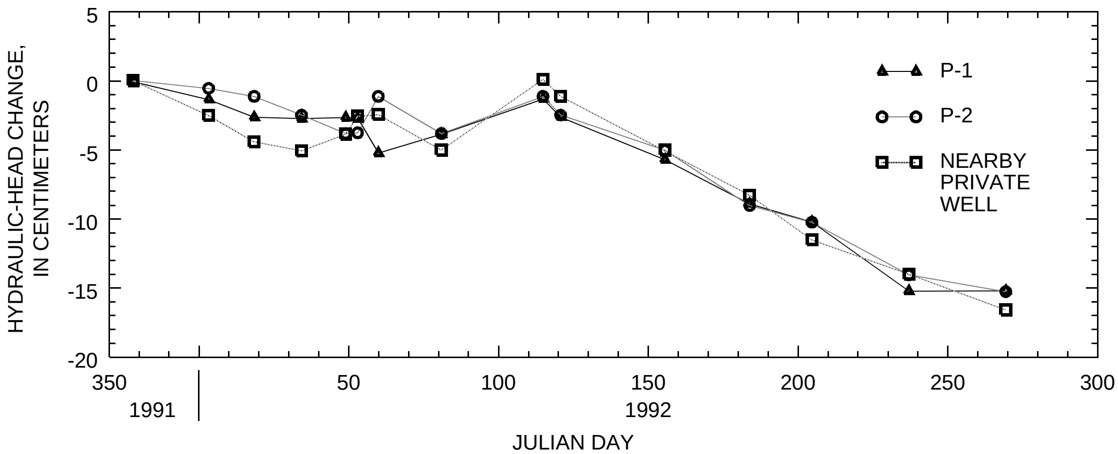

Figure 2. Hydraulic-head changes measured at two piezometers and a nearby domestic well at the field site between December 1991 and September 1992 (Haneberg and Friesen, 1993; Friesen, 1992). Locations of piezometers P-1 and P-2 are shown in figure 1.

Long-term records (tens to hundreds of days) show complicated patterns of tilt both towards and away from the fissure (fig. 3)These patterns are inconsistent with the notion of simple plane strain perpendicular to the fissure, and tilt measurements are only weakly correlated with long-term changes in water level near the fissure. Tilts calculated using a model of a thin elastic plate subjected to spatially-variable loading, for example due to differential compaction over the buried channel deposit beneath the site (see Haneberg abstract), lead us to speculate that highly variable tilts may be caused by flexure of surficial layers over buried stratigraphic and structural irregularities above the water table (Haneberg and Friesen, 1993).

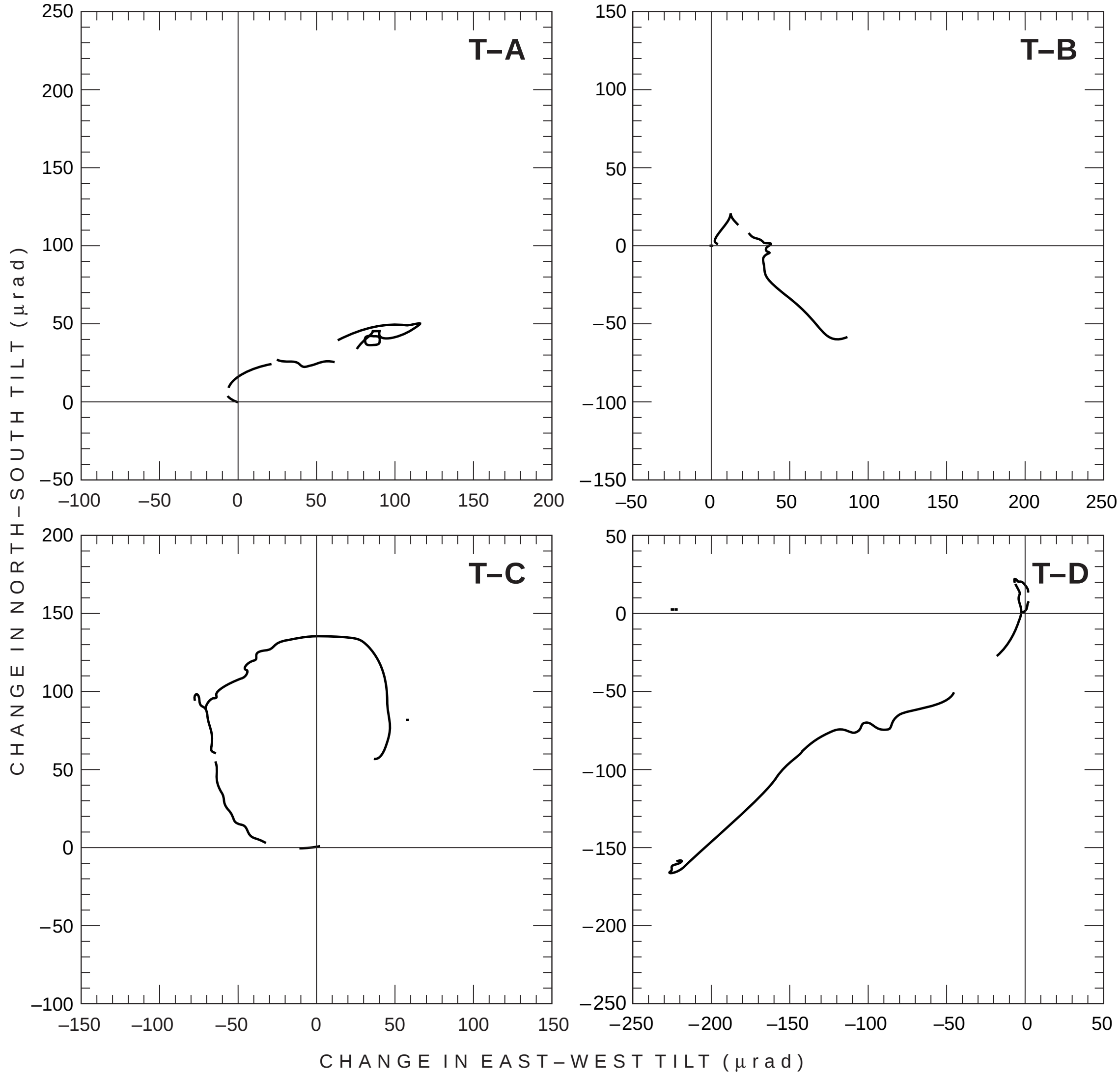

Figure 3. Plan views of data obtained from tiltmeters T-A, T-B, T-C, and T-D near the Cox earth fissure between mid-January and late September 1992. Instrument locations are shown in figure 1. Although the E-W and N-S ranges are the same magnitude for individual tiltmeter plots, the ranges vary among plots according to the amount of tilt measured. During the period of record, tiltmeter A tilted down towards the northeast, tiltmeter B tilted down towards the southeast, tiltmeter C tilted down towards the northeast, and tiltmeter D tilted down towards the southwest.